

FINAL YEAR PROJECT 2
ENERGY CONVERSION FROM DC GENERATOR PART IN WIND TURBINE TO
PRODUCE ELECTRICITY

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ABSTRACT

A wind turbine is a rotating machine which converts the kinetic energy of wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is usually called a windmill. If the mechanical energy is instead converted to electricity, the machine is called a wind generator, or more commonly called a wind turbine. This study presents of doing an experiment of a simple wind turbine. The project is to analyze the suitable DC motor that can act as generator part in wind turbine and operate properly. Besides that, the wind turbine should generate electricity as it functions. For this process, after choosing the suitable DC generator, an experiment was undergone to determine the output voltage which is the electricity and also to check whether the DC generator operates properly. Actually the experiment was undergone using wind velocity that can be gain around us but because the wind velocity is too slow and not windy, I am using the wind velocity from fan and act as the alternative method to undergo the experiment. So to make sure that all the objectives for the Projek Sarjana Muda is achieved, the experiment and procedure must be done properly and also by referring the scope of the project.

ABSTRAK

Sebuah turbin angin adalah sebuah mesin berputar yang menukarkan tenaga kinetik angin kepada tenaga mekanikal. Jika tenaga mekanikal digunakan secara langsung oleh jentera, seperti pam atau batu pengisar, mesin biasanya dipanggil kincir angin. Jika tenaga mekanikal sebaliknya ditukar kepada elektrik, mesin dipanggil penjana angin, atau lebih dikenali sebagai turbin angin. Kajian ini membentangkan menjalankan eksperimen turbin angin mudah. Projek ini adalah untuk menganalisis motor DC yang sesuai yang boleh bertindak sebagai sebahagian penjana dalam turbin angin dan beroperasi dengan betul. Selain itu, turbin angin yang perlu berfungsi perlu menjana elektrik. Untuk proses ini, selepas memilih penjana DC yang sesuai, eksperimen telah dijalankan untuk menentukan keluaran arus voltan elektrik dan juga untuk memeriksa sama ada penjana DC beroperasi dengan betul. Sebenarnya eksperimen telah dijalankan menggunakan halaju angin yang boleh terdapat di sekeliling kita tetapi oleh kerana halaju angin yang terlalu perlahan dan tidak berangin, saya menggunakan halaju angin dari kipas angin dan bertindak sebagai kaedah alternatif untuk menjalani eksperimen. Jadi untuk memastikan bahawa semua objektif untuk Projek Sarjana Muda dicapai, eksperimen dan prosedur perlu dilakukan dengan betul dan juga dengan merujuk skop projek.

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LIST OF SYMBOLS

T	=	rotor torque
B	=	magnetic flux
R	=	average winding radius
l	=	effective conductor length (stack length)
Z	=	number of conductors
i	=	current flowing in the conductor
V	=	induced voltage
$\overline{v_y}$	=	velocity of inductor perpendicular to the magnetic field
$\overline{B_x}$	=	magnetic flux vector
RPM	=	rotation per minute
ω	=	angular velocity
P	=	power

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

“Wind energy” or “wind power” describes the process which is used wind to generate mechanical power. This mechanical power can be used for specific tasks or a generator can convert this mechanical power into electricity to power homes. Wind turbines turn in the moving air and power on electric generator that supplies an electric current.

Wind turbine work is like a fan but fan using electricity to make wind, however wind turbines turns the blade which spin a shaft, then connects to generator and lastly it will makes electricity. In energy-generating windmills, the shaft is connected to an induction generator inside the structure. The wind turns the fans, which provides the kinetic energy to spin the wires in the generator

Wind power means using the wind - harnessed by either a turbine, wind mill, wind pump or even sails (for ships) - to generate the desired amount of electricity to be used for home and commercial purposes. This provides an efficient power alternative that is clean, abundant and completely environmentally friendly. This means that a natural resource is used to produce clean, environmentally friendly power.

The most common ways of harnessing the power of the wind is using sails to propel ships and sail boats across the water. The most desirable way of using the wind to generate electricity is by erecting wind turbines.

There are two categories of wind turbines: the horizontal axis design (HAWT) and the vertical axis design (VAWT). Since it is the more practical and popular, the HAWT enjoys more attention than its sibling, the VAWT.

The HAWT has its main rotor shaft at the top of the column along with the electrical generator. The turbines must be pointed into the wind and is positioned favourably by either a small weathervane or a wind sensor. The rotor shaft and gearbox of the VAWT are positioned vertically and are also installed near the ground. This makes it more accessible for maintenance and other necessary adjustments. One of the reasons why this type of wind turbine is less popular is that it can produce what is known as pulsating torque.

As the wind turns the blades of the turbine they, in turn, turn the shafts running down the tower and are connected to a generator. The working of the shafts and the friction of the turning shafts link into the generator which then converts the energy created by the wind turbine into the useful electricity that is needed.

Windmills works in 3 parts :-

- 1) Blades (the parts that look like fan) - “catch” the wind. Sitting at a slight angle to the direction of the wind, the blades are pushed in a circle as the wind blows against them.
- 2) Hub of the windmill – like the hub of a wheel, with the fans sticking out like spokes around it. Then the fans turn the hub as they move in a circle.
- 3) The part where hub is attached to the shaft, which spins as the hub spins. The shaft is connected to whatever mechanism the windmill is designed to turn such as generator part.

After finish the blade part, the next part is induction generators. Windmills that generate energy contain induction energy. It does not make energy, but rather converts kinetic (physical) energy into electrical by spinning a wire within a magnetic field, which causes an electrical current to flow through the wire.

1.2 PROBLEM STATEMENT

During the development of generator part for wind turbine, the analysis of each element need to be criticized so that the specific component used can be known. The details of type of material used also must consider in order determining the production of generator part of wind turbine experiment. Therefore, analysis must be done in order to know the strength and weakness of making the generator part in order to produce the output voltage.

1.3 OBJECTIVE

The objectives of this study are:

- To generate the DC permanent magnet motor as generator part in wind turbine.
- To gain the output power from the shaft rotation of DC permanent magnet motor.

1.4 SCOPE OF STUDY

- Literature review and study of wind turbine generator.
- Research and analysis component that use in generator part.

CHAPTER 2

LITERATURE REVIEW

2.0 DESCRIPTION

Literature review and research on theories related to the projects begin after the title of project was decided. These involve theories of numerous of wind turbine by obtaining most of the information from the internet and a few reference book. Small scale wind turbine was chosen to be developed in this project because it was relevant based on size and cost involved.

2.1 EXPERIMENT

F. Wang, L. Bai, J. Fletcher, J. Whiteford, and D. Cullen (2007) studied on a small domestic wind turbine with scoop. The aim of this study is to investigate the possibility of improving wind energy capture, under low wind speed conditions, in a built-up area, and the design of a small wind generator for domestic use in such areas. The activities reported in this paper are optimization of a scoop design and validation of the CFD model. The final design of scoop boosts the air flow speed by a factor of 1.5 times equivalent to an increase in power output of 2.2 times with the same swept area. Wind tunnel tests show that the scoop increases the output power of the wind turbine. The results also indicate that, by using a scoop, energy capture can be improved at lower wind speeds. The power generation of such a new wind turbine is expected to be increased, particularly at locations where average wind speed is lower and more turbulent.

A.K. Wright and D.H. Wood (2007) analyze that the magnitude of gyroscopic rotor shaft and blade bending moments on a free yaw wind turbine rotor are proportional to the product of rotor speed and yaw rate. An analysis is presented of the relationship between two variables and wind speed, based on field test data from a 2 m diameter wind turbine with a tail-fin furling system, and in reference to the recent revision of the International Electro technical Commission standard for small wind turbine design. Examples are given of fast yaw rates caused by furling, and by large wind direction changes at relatively small wind and rotor speeds. Analyses of data showed that reducing turbine yaw moment of inertia increases the magnitude of maximum yaw rate for a given rotor speed, and that yaw rate is highly influenced by tail fin aerodynamics.

2.2 THEORETICAL ANALYSIS

S. Roy (1997) studied on optimal planning of wind energy conversion systems over an energy scenario. The wind power system design must optimize the annual energy capture at a given site. The only operating mode for extracting the maximum energy is to vary the turbine speed with varying wind speed such that at all times the TSR is continuously equal to that required for the maximum power coefficient. The theory and field experience indicate that the variable-speed operation yields 20 to 30% more power than with the fixed-speed operation. In the system design, this trade-off between energy increase and cost increase has to be optimized. In the past, the added costs of designing the variable pitch rotor, or the speed control with power electronics, outweighed the benefit of the increased energy capture. However, the falling prices of power electronics for speed control and the availability of high-strength fiber composites for constructing high-speed rotors have made it economical to capture more energy when the speed is high.

J.S. Rohatgi and V. Nelson (1994) present the analysis for the generation of wind power. Power regulation and control issues must be addressed in a modern HAWT. When the wind speed increases to a value at which the generator is producing rated power, some control action must occur so that the generator does not exceed its rated capacity and overheat. Typical methods of power regulation at rated wind speed are pitch regulation, stall regulation, and yaw control or furling. Pitch regulation is accomplished by providing rotating bearings at the blade root and actively changing the blade pitch angle relative to the wind, thus regulating power. Stall control is accomplished by designing the rotor so that aerodynamic stall is reached at rated wind speed and the rotor power is limited by airfoil stall. Yaw control or furling turns the entire rotor out of the wind either vertically or horizontally at rated wind speed and regulates power by reducing the rotor area exposed to the wind. The latter approach is generally only employed on small wind turbines.

2.3 WIND TURBINE RESEARCH

Wind turbine is a rotating machine which converts the HT kinetic energy T_H in HT wind T_H into HT mechanical energy. The developments of wind turbine start since 200 B.C which in Persia but until 250 A.D the usage of wind turbine had been introduced by Roman Empire. In 7th century, the first vertical axle windmills had been developing at Sistan, Afghanistan. These windmills had long vertical drive shafts with rectangle shaped blades. It was made of six to twelve sails covered in reed matting or cloth material and used to grind corn and draw up water and was used in the grist milling and sugarcane industries.

Besides that, wind turbine technologies still grown up until 1908 at United States. There have 72 wind-driven electric generators from 5 kW to 25 kW. The largest machines were on 24 m (79 ft) towers with four-bladed 23 m (75 ft) diameter rotors. Around the time of World War I, American windmill makers were producing 100,000 farm windmills each year, most for water-pumping.

However in 1954, the first utility grid-connected wind turbine operated was built by the John Brown Company at Orkney Islands, United Kingdom. It had an 18 meters diameter, three-bladed rotor and a rated output of 100 kW. From 1955 until nowadays, every country want to used these technologies as alternative and renewal energy. More developments and research have been done to use wind turbine as renewal energy because have more advantages for natural. There have 3 level of range for the wind turbine. They are large scale for 500 kW until 5 MW, medium scale between 10 kW until 500 kW and the small scale is below than 10 kW.

2.4 ADVANTAGE OF WIND TURBINE

Wind for now is the renewable energy, that's why we use wind turbine energy for resource and technology of choice. The most important is it was a "free" resource and naturally. Also its a "clean" resource due to replacement of a "dirty" energy source (coal) and no emissions associated with its use. Wind turbine can be utilized on underutilized land or on lands and currently in commodity crop production. Also which is can be "harvest" on the surface and "harvest" above the surface. Then it will primarily be used for electricity generation for immediate end-use.

Wind turbine one of the best choose that we have because it was no air emissions and also don't have Greenhouse Gas Emissions. The most important is, it no need for fuel to mine, transport, or store for the source. It also don't need any equipment like cooling water that we always use at fuel engine and nuclear reactor. There are free from making pollution for example water pollution that always produces by human activity. After all there is no waste when used wind turbine.

2.5 SMALL WIND TURBINE

In this project, I need to build a prototype of inner component in the wind turbine that can converting the energy of the wind into mechanical energy. Wind power is the conversion of wind energy, such as using wind turbines to make electricity .

The vast majority of wind turbines consist of rotor blades which rotate around a horizontal hub. The hub is connected to a gearbox and generator, which are located inside the nacelle. The nacelle houses the electrical components and is mounted at the top of the tower. In a grid-tied configuration the electricity from the generator is routed to an inverter which converts the electricity from direct current (DC) to the alternating current (AC) that electrical grids use. [3]

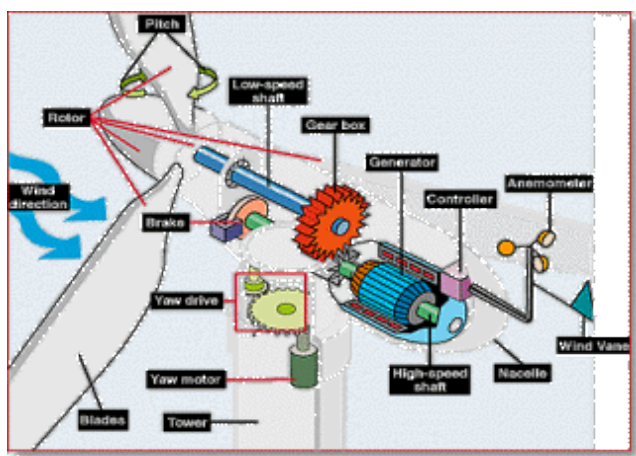
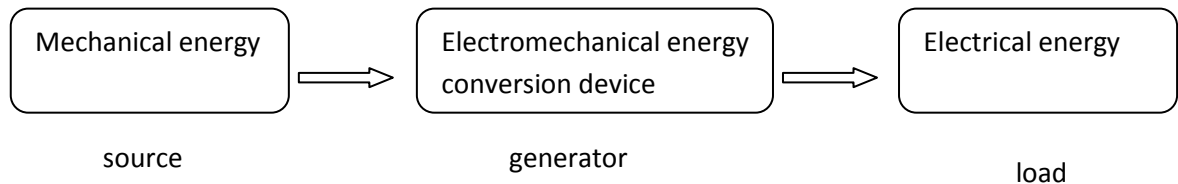


Figure 2.1 : Wind Turbine Close Up

System operation of wind turbine is when the rotor begins to rotate (spin) after the wind speed reaches, the battery charging commences at a slightly higher speed, depending on the battery state of charge. Then when the battery is fully charged, the charge controller disconnects the turbine from the battery. The turbine will produces a three phase alternating current (AC) that varies in voltage and frequency as the wind speed varies. Next ,the controller (regulator) rectifies this AC into the direct current (DC) required for battery charging and controls the energy supplied to the batteries to avoid overcharging.

2.5.1 BASIC COMPONENT



- Electromechanical energy conversion occurs when there is a change in magnetic flux linking a coil, associated with mechanical motion.
- DC motors consists of one set of coils, called armature winding, inside another set of coils or a set of permanent magnet, called the stator.
- Stator :
 - Stationary outside part of a motor.
 - Stator of a permanent magnet DC motor is composed of two or more permanent magnet pole pieces.
 - Magnetic field can alternatively be created by an electromagnet.
- Rotor :
 - Inner part which rotates
 - Compose of winding (called armature windings) which are connected to the external circuit through a mechanical commutator
 - Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap
- Winding:
 - Made up of series or parallel connection of coils
 - Armature winding : the winding through which the voltage is applied or induced
 - Field winding : the winding through which a current is passed to produce flux (for the electromagnet)
 - Windings are usually made of copper.

2.5.2 PERMANENT DC MOTOR

Electromechanical energy conversion employing generators and motors play a crucial role in energy consumption and production. Permanent magnet technology represents a new enhanced area that can be used both in generators and motors. Permanent magnet motors are well-known class of rotating and linear electric machines used in both motoring and generating modes. Permanent magnet machine describes all electromagnetic energy conversion devices in which the magnetic excitation is supplied by a permanent magnet or several permanent magnets. The energy converters using permanent magnet include a variety of configurations, and such terms as motor, generator, alternator, stepper motor, linear motor, actuator and many others to describe them.

A machine with a high torque or high power density and high efficiency at a low design operating speed can be considered for the direct-drive wind turbine application. A machine's ability to provide a significant reduction in the cost of converting wind derived mechanical power to electric power by eliminating the geared speed increaser, typically used into wind power applications. For this reason, the technology of low-speed, high-torque motors requires scrupulous evaluation in order to determine their suitability for a direct-drive wind turbine application.

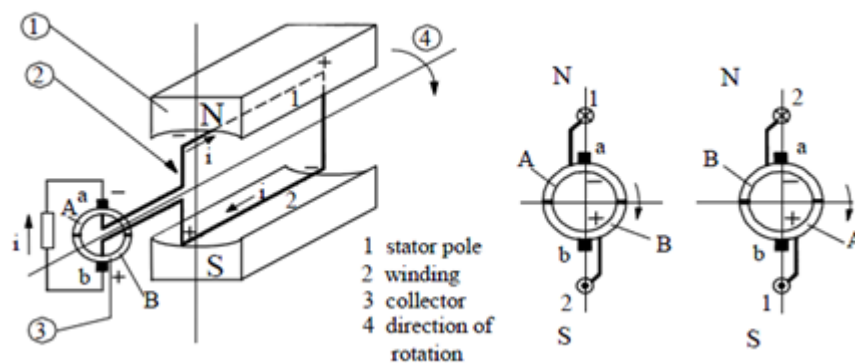


Figure 2.2 : Principle Of A Rotating DC Machine

The principle can directly be used to develop a 2-pole rotating DC machine. Motor as well generator operation can be derived from figure above. The collector or commutator guarantees the unidirectionality of the current.

We can use permanent magnet motors, because they are widely available, reliable because of the nature of their construction, and start generating electricity at almost any RPM. Inside a permanent magnet motor is a coil of wound copper surrounded by permanent magnets. These type of motors rotate using electromagnetic induction, which means electricity is supplied to wound copper wire which creates a magnetic field. The magnetic field created by the electricity flowing through the copper wire opposes the permanent magnets in the motor housing. As a result, the copper wire that is attached to the shaft of the motor tries “to push” itself away from the permanent magnets. So your motor starts spinning.

2.5.3 PERMANENT MAGNET GENERATOR

Random output variation is one of the significant characteristics of wind power. With a PM generator coupled to a wind turbine, the voltage output will be varying with its rotor speed because of the wind speed variation. A permanent magnet generator has no excitation control and hence produces a voltage proportional to the shaft speed which in turn varies with the wind speed. The earliest and still most widely used power electronic circuit for this application uses an AC/DC/AC technology in which the variable frequency, variable voltage from the generator is first rectified to DC and then converted to AC and fed to the grid

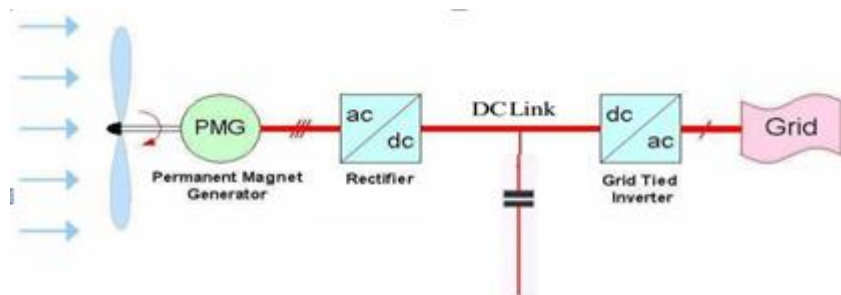


Figure 2.3 : AC/DC/ AC Power Electronic Interface For A Wind Generator

(Figure 2.3). The continuous variation of wind speed will result in a DC link voltage varying in an uncontrolled manner with a more demanding role and specification for the DC-AC inverter.

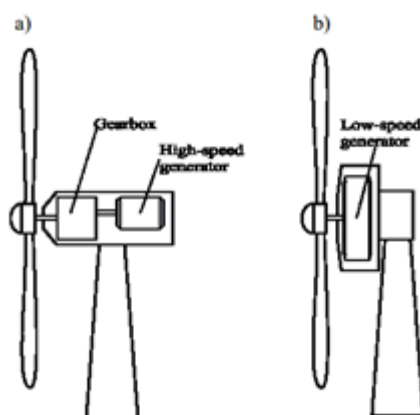


Figure 2.4 : Typical Structures Of Gearbox-Generator (a) And Direct-Drive Generator (b) Of A Wind Power Plant

Permanent-magnet (PM) synchronous generators are one of the best solutions for small-scale wind power plants. Low-speed multiple PM generators are maintenance-free and may be used in different climate conditions. The use of a gearbox causes many technological problems in a wind power plant, as it demands regular maintenance, increases the weight of the wind plant, generates noise and increases power losses. These problems may be avoided using an alternative – a direct-drive low-speed PM synchronous generator (Fig. 2.4b).

2.5.4 LOW-SPEED DIRECT-DRIVE PERMANENT MAGNET SYNCHRONOUS GENERATORS

In small-scale wind power plants very often low-speed direct-drive synchronous generators are used. Due to low rotational speed of the synchronous generator directly connected to the mechanical shaft of the wind rotor, the generator has a multiple construction. A synchronous generator may be excited by traditional current-carrying field winding or by permanent magnet system of high energy. Synchronous generators with permanent magnet excitation for small-scale wind power units are more maintenance-free and reliable in long-term exploitation. The generators were of a conventional construction of a typical synchronous generator with radial magnetic flux in the air gap between the inner rotor and the outer stator.[2] Alternator are designed to charge (storage) batteries (accumulators). Then, the alternator converts the mechanical (rotational) energy of the rotor into electricity (three phase alternating current). The magnets are in the rotor, which allows suppression of the rings and brushes for connection. The number of poles will improves the alternator performance at low speed, increases the mechanical parts life and reduces the noise level. The rotor system allows the efficient conversion of wind linear movement in to alternator rotational movement.

2.5.5 EMULATOR CONSTRUCTION

The emulator is based on the energy conversion system shown in 2.5. The laboratory system is realized by replacing the gearbox, wind and turbine rotor with a PC, ac–dc converter, dc drive, and dc motor as shown in Fig. 2.6. The PC implementing MATLAB/Simulink uses a wind shear/tower shadow model, an inertia model, steady-state characteristics, and a variable wind to control the dc system to emulate the driving torque of a wind turbine. These models will be briefly outlined as well as the computer hardware components along with the drive equipments.[1]

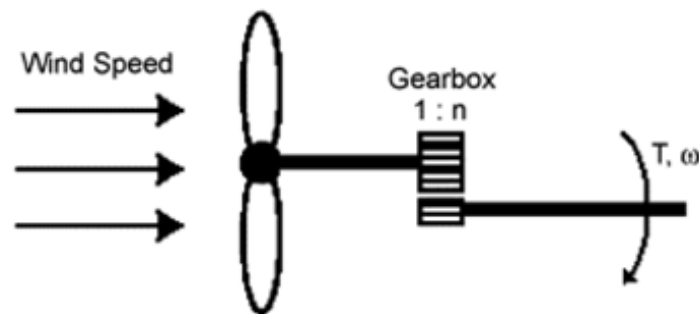


Figure 2.5 : Wind Turbine System

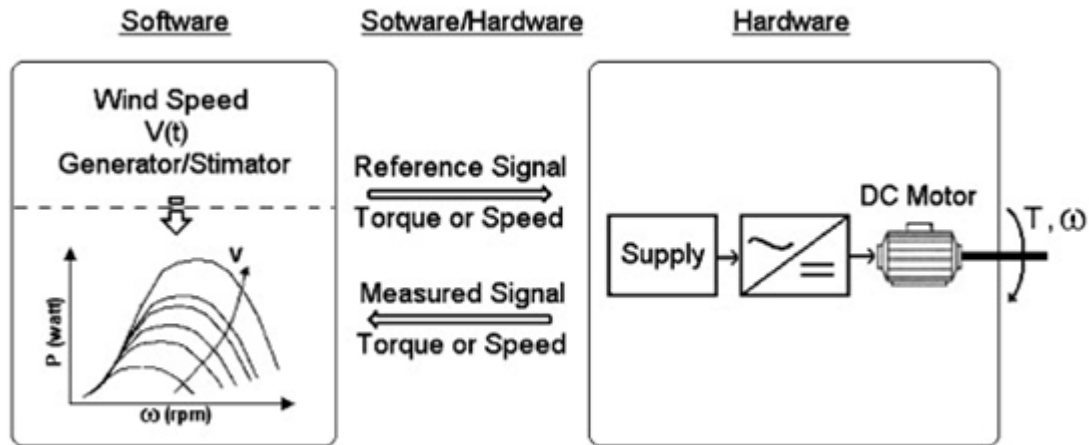


Figure 2.6 : Wind Turbine Simulator System

2.6.6 VARIABLE SHAFT SPEED OPERATION

In the wind turbine systems, the turbine is allowed to rotate at different speeds with the varying wind speed. It is usually desired to ensure optimum power transfer. The actual speed of rotation is determined by the torque versus speed characteristics of both the turbine and the generator. In the operating mode, major control means are inevitably placed on the electrical side. Obviously, the control of electrical systems is easy to implement, more reliable and less costly than the control of mechanical systems. In addition, synchronous machines may be used in variable shaft speed. In this case, operation of the system at the most efficient working condition is possible.